Parallel Algorithms and Architectures for Computational Structural Mechanics

(Grant. No. NAG-1-466)

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Abstract

The determination of the fundamental (lowest) natural vibration frequencies and associated mode shapes is a key step used to uncover and correct potential failures or problem areas in most complex structures. However, the computation time taken by finite element codes to evaluate these natural frequencies is significant, often the most computationally intensive part of structural analysis calculations. There is continuing need to reduce this computation time. This study addresses this need by developing methods for parallel computation.

DUKE'S CSM SUPPORTED ACTIVITY

- SPECIFIC OBJECTIVES
- METHODS

DUKE'S CSM SUPPORTED ACTIVITY

Duke's research group is developing parallel methods for solving the generalized eigenproblem of the form $Kx = \lambda Mx$, where K and M are symmetric and M is positive definite. Two methods are being implemented. They are based on subspace iteration (see ref. 2) and spectrum sectioning (see ref. 3). The methods are being tested with stiffnesses matrices, K, and mass matrices, M, obtained from NICE/SPAR runs on two focus problems, space mast problem and stiffened panel problem. The research is closely coordinated with that of the NASA Langley CSM group (see ref. 1).

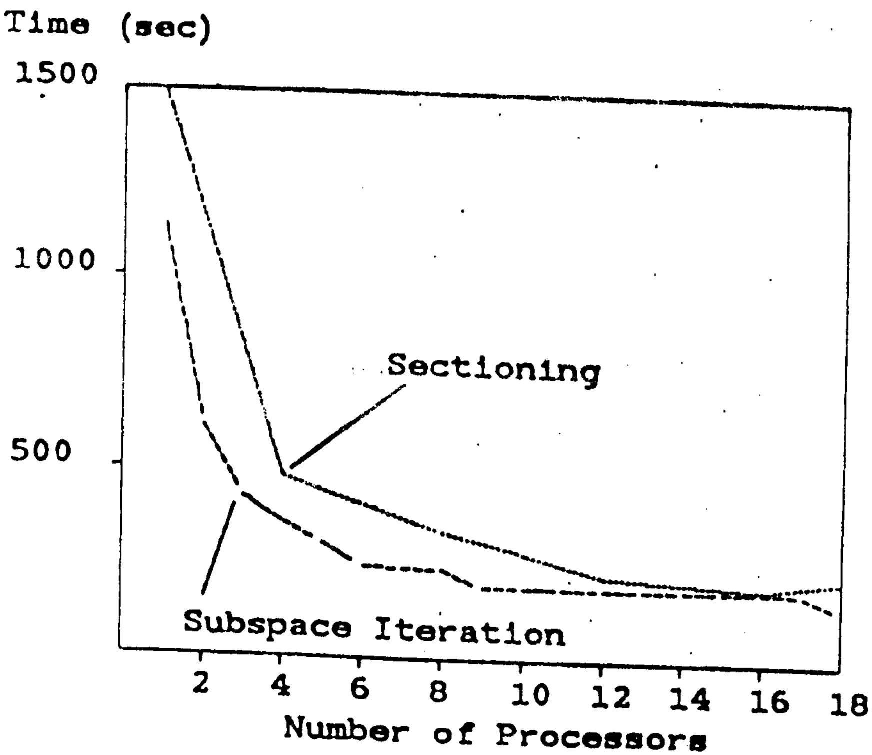
EXPERIMENTAL RESULTS - I

SOLVE : $Kx = \lambda Mx$ (10 lowest eigenpairs)

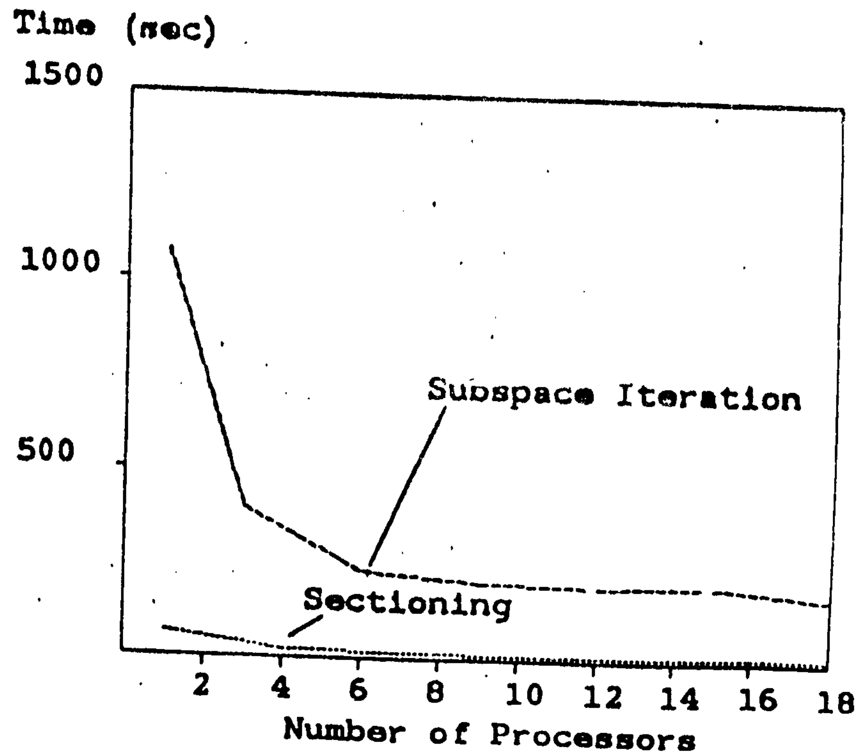
PARALLEL METHODS : Sectioning
: Subspace Iteration

Execution Time Vs Number of Processors

54-Bay Space Mast
K : dimension 486, bandwidth 35
M : diagonal



One Dimensional Poisson's Equation
K : dimension 486, bandwidth 3
M : I



EXPERIMENTAL RESULTS – I

The graphs pictured above compare execution times versus number of processors of the parallel sectioning and subspace iteration methods for two different sets of test matrices. Objective of the commparison is to show the impact of the bandwidth on performance of the methods.

Clearly, bandwidth affects the relative performance of the two methods with parallel sectioning having superior performance for the small bandwidth problem but losing that superiority to the parallel subspace iteration method for the large bandwidth problem.

EXPERIMENTAL RESULTS - II

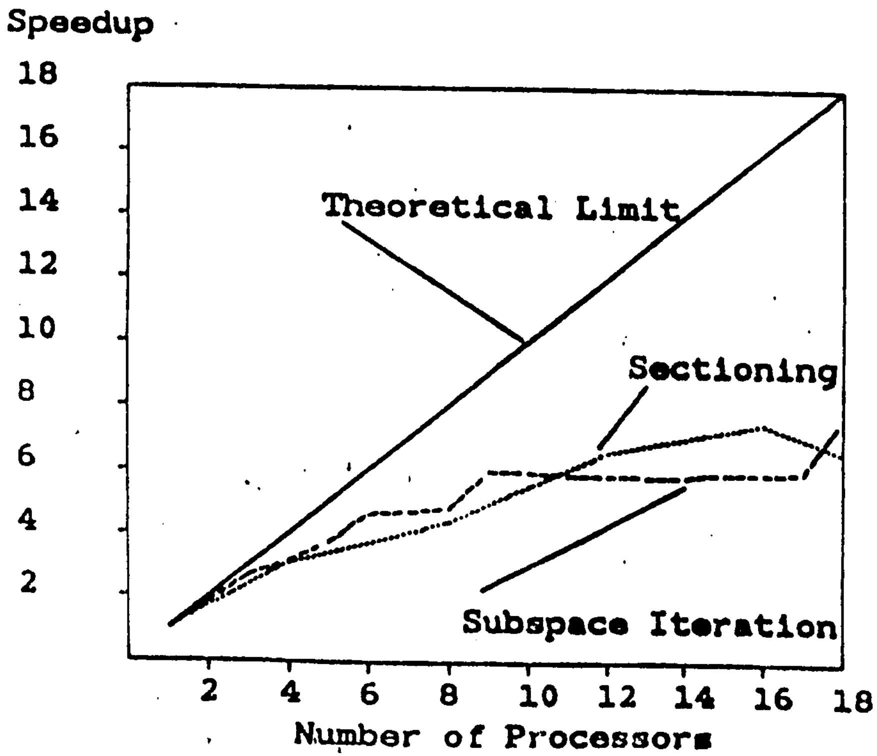
SOLVE : $Kx = \lambda Mx$ (10 lowest eigenpairs)

PARALLEL METHODS : Sectioning

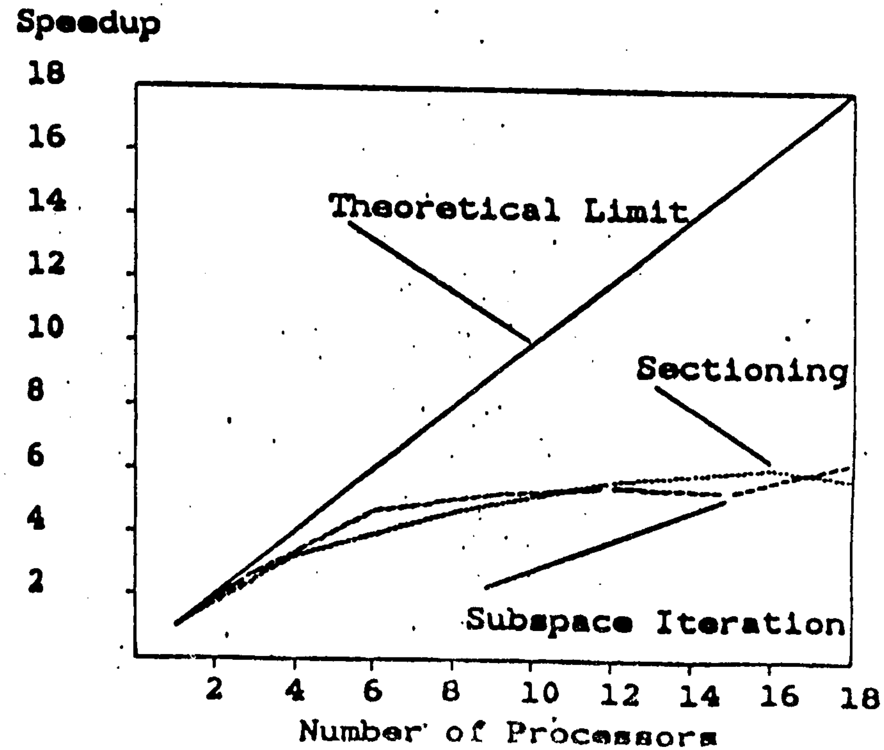
: Subspace Iteration

Speedup Vs Number of Processors

54-Bay Space Mast
K : dimension 486, bandwidth 35
M : diagonal



One Dimensional Poisson's Equation
K : dimension 486, bandwidth 3
M : I



EXPERIMENTAL RESULTS – II

Speedup versus number of processors of the parallel sectioning and subspace iteration methods for two sets of matrices are compared. It should be noted that the parallel sectioning method cannot yield a speedup higher than the number of eigenvalues being computed, 10 in this case. Hence parallel sectioning method comes closer to its theoretical maximum than does the subspace iteration method.

EXPERIMENTAL RESULTS - III

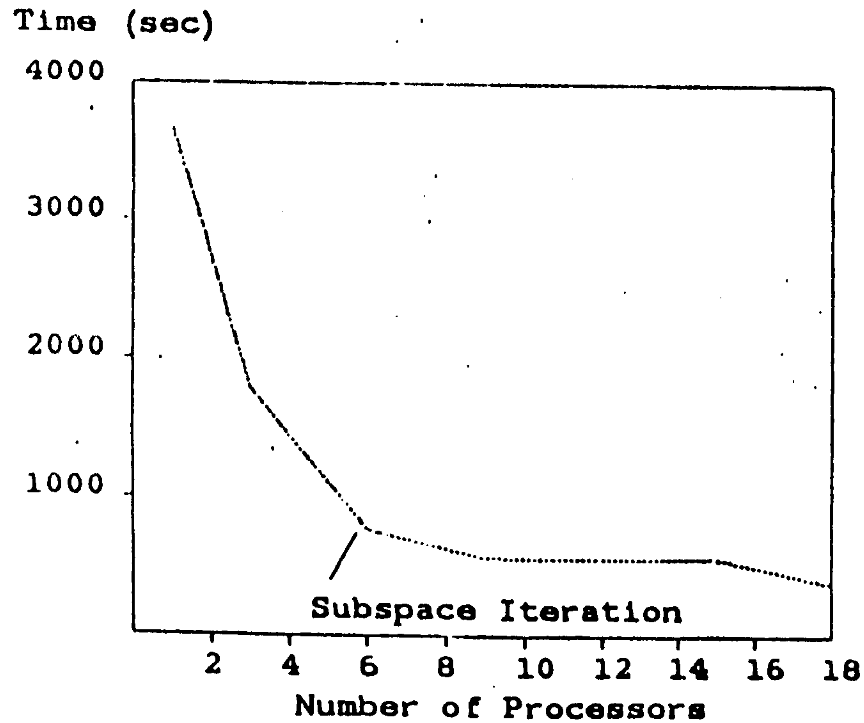
SOLVE : $Kx = \lambda Mx$ (10 lowest eigenpairs)

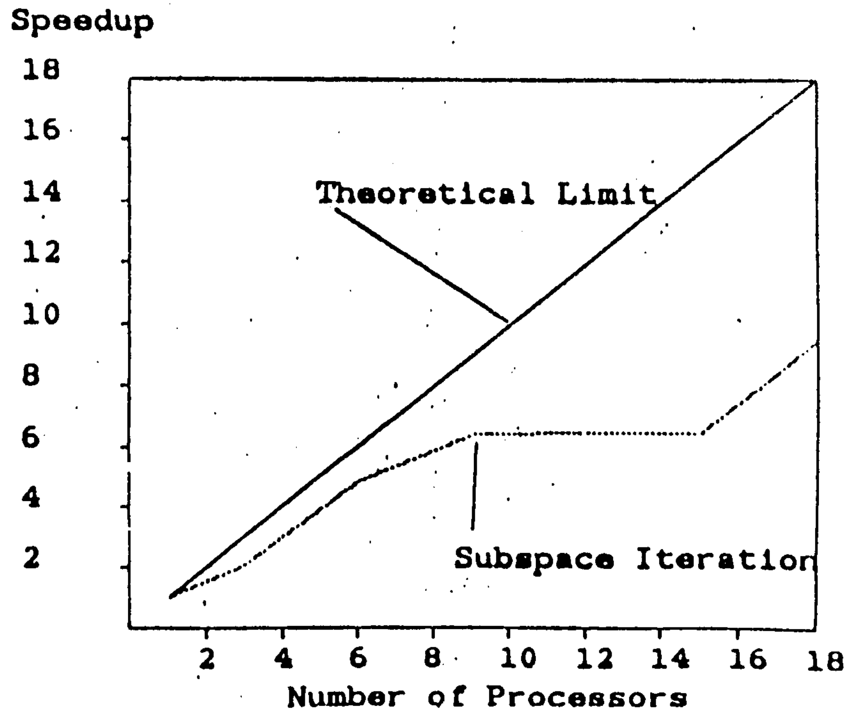
PARALLEL METHOD : Subspace Iteration

Execution Time Vs Number of Processors

Speedup Vs Number of Processors

Stiffened Epoxy Panel
K : dimension 456, bandwidth 223
M : diagonal





EXPERIMENTAL RESULTS – III

Both execution time and speedup versus number of processors of the parallel subspace iteration method for the stiffened epoxy panel problem with 456 degrees of freedom and bandwidth are shown. Corresponding graphs for the parallel sectioning were not included because its execution time for this higher bandwidth problem had grown to hours, which indicates its unsuitability for solving high bandwidth problems. The increased execution time is due to the increased time required to factor $K - MM$ for higher bandwidth K and M. A factorization is required each time the spectrum is sectioned or sliced (see ref. 1).

CURRENT AND FUTURE EFFORTS

- LARGE SCALE MODELS OF FOCUS PROBLEMS
- IMPROVEMENT OF METHODS
- COMPARISON OF PARALLEL LANGUAGES FOR SCIENTIFIC COMPUTING

CURRENT AND FUTURE EFFORTS

- **Large Scale Models of Focus Problems**

  Our parallel methods for solving the generalized eigenvalue problem are being tested on larger scale models of the two focus problems. With the FLEX/32 upgrade, much larger problems can now be solved. How much larger is yet to be determined.

- **Improvement of Methods**

  The parallel subspace iteration method is being improved by adding shifting to the inverse iteration loop of the method. This was not added initially because shifting requires solutions of indefinite linear systems. This change should decrease substantially the number of iterations and improve the overall performance of subspace iteration.

- **Comparison of Parallel Languages for Scientific Computing**

  In addition to the development of parallel methods, we are comparing different parallel programming languages available. These languages include Concurrent FORTRAN, Force, PISCES, and Schedule. Points of comparison include expression of functional and data parallelism, communication annd synchronization mechanisms, ease of learning language, readability of program, and testing and debugging support.

REFERENCES

1. Knight, N.F., and Stroud, W.J., "Computational Structural Mechanics: A New Activity at the NASA Langley Research Center," NASA TM 87612, September, 1985.

2. Bathe, K., Finite Element Procedures in Engineering Analysis, Prentice-Hall, Inc., 1982.

3. Peters, G., and Wilkinson, J.H., "Eigenvalues of $Ax = \lambda Bx$ with Band Symmetric A and B," Computing Journal, Vol. 12, 1969, pp. 388-404.